

Penetration of UV Radiation in the Earth's Oceans
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Final Report

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Abstract

This project was a collaboration between SIO/UCSD and NASA/GSFC to develop a global estimation of the penetration of UV light into open ocean waters, and into coastal waters. We determined the ocean UV reflectance spectra seen by satellites above the atmosphere by combining existing sophisticated radiative transfer models with in situ UV Visible data sets to improve coupled radiance estimates both underwater and within the atmosphere. Results included improved estimates of surface spectral irradiance, 0.3-1.0 μm , and estimates of photosynthetic inhibition, DNA mutation, and CO production. Data sets developed under this proposal have been made publicly available via submission to the SeaWiFS Bio-Optical Archive and Storage System. Numerous peer-reviewed publications and conference proceedings and abstracts resulted from the work supported by this research award.

Work completed at SIO/UCSD

The broad goals were to develop advanced parameterization of the UV optical properties for ocean water by combining laboratory and in-situ absorption and scattering data with published pure water estimates. Specifically, we exploited our large global data set of UV-visible optical properties determined in diverse regions of the oceans during the past 10 years (Figure 1). Using models, we applied satellite radiance measurements to determine the bulk characteristics (absorption) of open ocean water to estimate penetration by UV-visible radiation into the upper ocean.

We explored the accuracy of the estimates of pure water absorption and developed new parameterizations for particulate absorption in the UV-visible region using chlorophyll as the biogeochemical variable. An example of how we have combined models and data is illustrated in Figure 2 where we plot the spectral backscattering coefficient estimated by introducing our measured UV-visible reflectance and absorption data into a model to solve for backscattering. We are evaluating the accuracy of this approach for the visible region where we have *in situ* estimates of backscatter. While UV estimates of backscattering are essential for ocean reflectance and radiative transfer models in the UV, no instruments yet exist for spectral estimates of *in situ* backscatter in the UV. Therefore, our analyses that exploit our detailed UV-visible reflectance and absorption data are as advanced as possible at this time for providing accurate estimates of UV backscattering coefficients. Optical parameterizations for absorption and backscattering have been provided to the team members at NASA GSFC who have included

them into preliminary models for system UV flux and ocean penetration. Global UV-Visible surface irradiance data sets collected at sea in the Antarctic, California Current and western Pacific regions have been provided to team members at NASA GSFC for validation of their UV-visible atmosphere radiative transfer model. Collaborating with our GSFC colleagues, the models have been compared to *in situ* UV-Visible surface reflectance using Hydrolight radiative transfer models (ACE Asia cruise example shown in Figure 3).

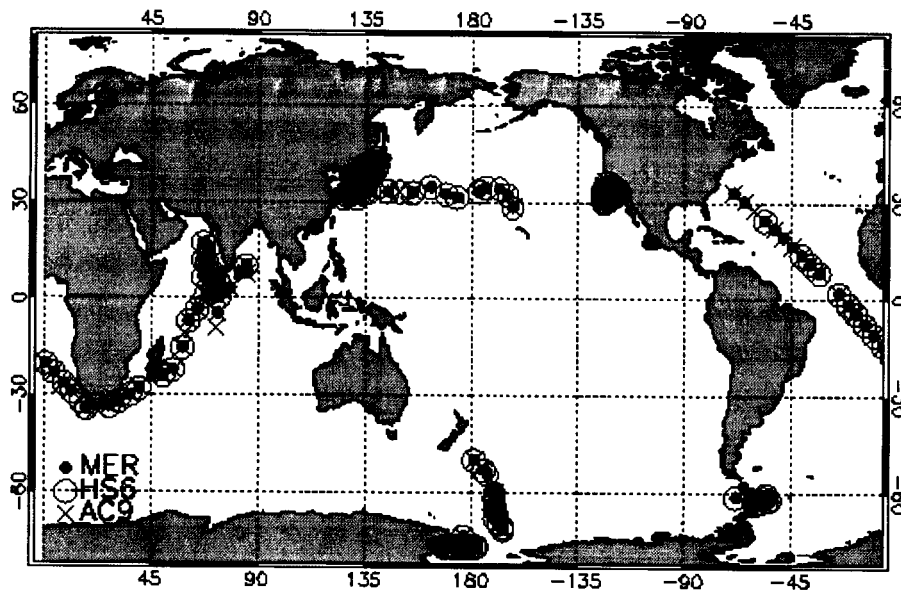


Figure 1. Global distribution of bio-optical stations collected in past 5 years. The detailed measurements have already been used for many improvements in ocean optical models and ocean color algorithms (O'Reilly et al., 1998; Mitchell and Kahru, 1998; Kahru and Mitchell, 1998; Kahru and Mitchell, 1999, Stramska et al., 2000; Loisel et al. 2001; Reynolds et al., 2001; Kahru and Mitchell, 2001). For this project further extended these data sets to include POC and particle size distribution in forward model parameterizations that were used in advanced inverse UV visible models of ocean radiative transfer.

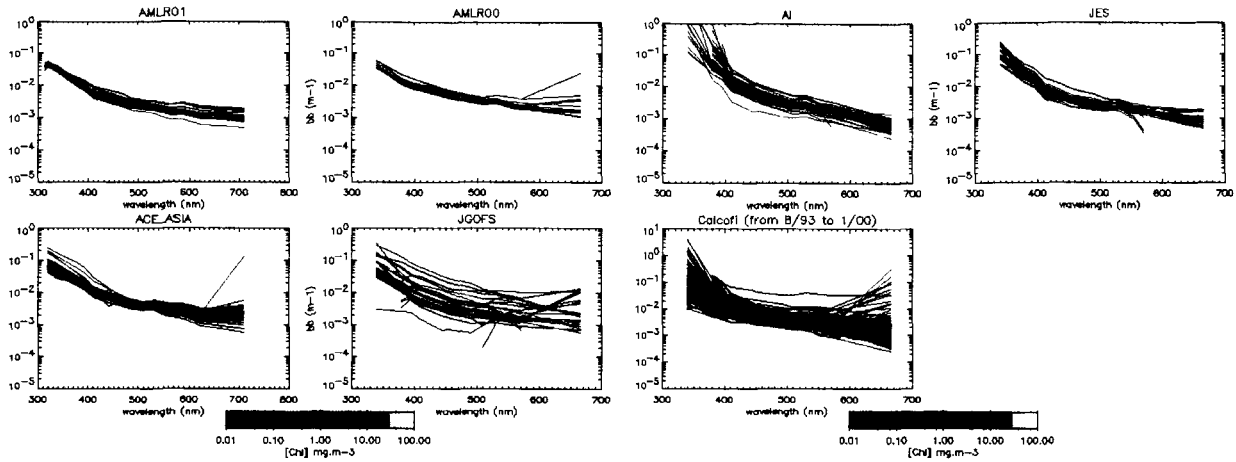


Figure 2. Estimates of $b_b(\lambda)$ for stations occupied during different cruises determined by introducing surface estimates of R_{rs} , a_p and a_g into Equation 2 (a_w from Pope and Fry, 1997; f/q from Reynolds et al., 2001). Each spectrum is color-coded based on the in situ concentration of chl-a based on the color scale that is provided. “Noisier” results from the JGOFS and CalCOFI data are attributed to profiling apparent optical properties from the ship’s A-frame with shadow, foam and bubble artifacts. Interestingly, the Atlantic and Indian Ocean data (AI) has relatively high computed backscatter and stronger spectral dependence for relatively low chl-a possibly caused by a preponderance of small particles.

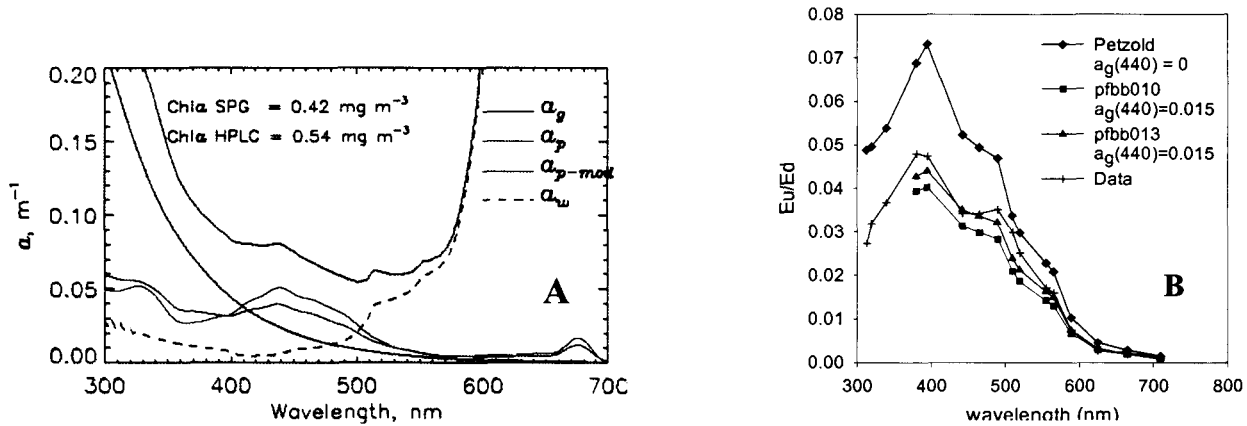


Figure 3. A. Spectral values of absorption by CDOM, particles and water for a station occupied during ACE-Asia. CDOM (blue) and the green line for particles were measured fresh the day of sampling. The red line is the prediction of particle absorption based on our global bio-optical data set (Park et al., 2000) (Figure 7). **B.** Comparison of the R_E (E_u/E_d) from PRR-800 estimates and Hydrolight model simulations where absorption was based on our parameterization (red line panel A). In the simulations, CDOM absorption was set to $a_g(440) = 0.015 \text{ m}^{-1}$ while the measured value was 0.02 at 440 nm. Fournier-Forand phase function with b_b/b ratios of 0.01 and 0.013 were used in these runs with no spectral dependency. Uncertainty in a is introduced depending on which chl-a estimate is used (SPG fluorometric or HPLC), the magnitude of CDOM at the reference wavelength (440), and the spectral shape of CDOM. The phase function and ratio of b_b/b also impacts the model estimate. We used in situ data sets as summarized here to develop an improved UV models for ocean radiative transfer that were validated with our global data sets and applied in various ways in the publications listed in this report.

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